A Survey of the Small Reef Fishes of Kāne'ohe Bay, O'ahu, Hawaiian Islands[1]

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Abstract: The small, sedentary fishes, many of which are cryptic, in Kāne'ohe Bay, O'ahu, Hawaiian Islands, were surveyed based on 75 small rotenone stations from 10 different habitats. These stations resulted in a total of 192 species from 48 different families. An additional 10 other small species were recorded from the bay in other samples ancillary to this study for a total of 202 species from 49 families. Assemblage structure for specific taxa was investigated using detrended correspondence analysis. Only the following taxa demonstrated various levels of clustering of stations from specific habitats in ordination space: Blennioidei, Labridae, Apogonidae, Gobiidae, Serranidae, and Anguilliformes. When these taxa were combined into a single analysis the distinctiveness of sheltered patch reefs within the bay from all other habitats was reinforced. These findings support earlier conclusions based on studies in the Atlantic Ocean that a search for a single model to explain assemblage structure of coral-reef fishes is ill founded.

THE FISHES OF KĀNE'OHE BAY have been studied more than those at any other location in the Hawaiian Islands because the University of Hawai'i's marine laboratory (Hawai'i Institute of Marine Biology) is located on Coconut Island (Moku o Lo'e) within the bay (Figure 1). In spite of this, most of the studies have involved larger, more obvious, colorful species such as the butterflyfishes and damselfishes or species of commercial importance such as the jacks. The smaller, often cryptic, species have received less attention; however, a major component of the fish fauna consists of small, cryptic species such as the blennies, gobies, cardinalfishes, small sea basses, and other families. These small fishes constitute the trophic link between the invertebrate fauna or algae on the reef and the larger fish species that feed primarily on smaller fishes (Norris and Parrish 1988). For example, Boehlert and Mundy (1996) reported that gobies of the genus *Eviota* composed the most abundant taxon in their ichthyoplankton samples taken near O'ahu, Hawai'i; they were five times more abundant than the next taxon, suggesting that even as larvae they must provide an important food source.

These small species also are important due to their sheer numbers on reefs, composing more than one-third of the species and more than half of the individuals from a specific locality in Fiji (pers. obs.). Studies by Miller (1979), Barlow (1981), Fishelson (1989), and Choat and Bellwood (1991) all further confirm the importance of small fishes in coral-reef habitats. Despite the abundance and importance of these small species, little is known of their community ecology compared with the larger coral-reef species (Munday and Jones 1998).

Gosline (1965) and Gosline and Brock (1960) provided information on the relationship between Hawaiian fishes and habitats but mainly in terms of vertical zonation. Some of their conclusions concerning the restriction of various species to specific zones, such as the splash or surge zones, are supported by this study. Hobson (1974) also provided information on habitats of a number of species, but mainly larger ones.

[1] This research was supported by grant no. R/E1-5PD from Sea Grant. Manuscript accepted 23 April 2002.

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Pacific Science (2003), vol. 57, no. 1:45–76

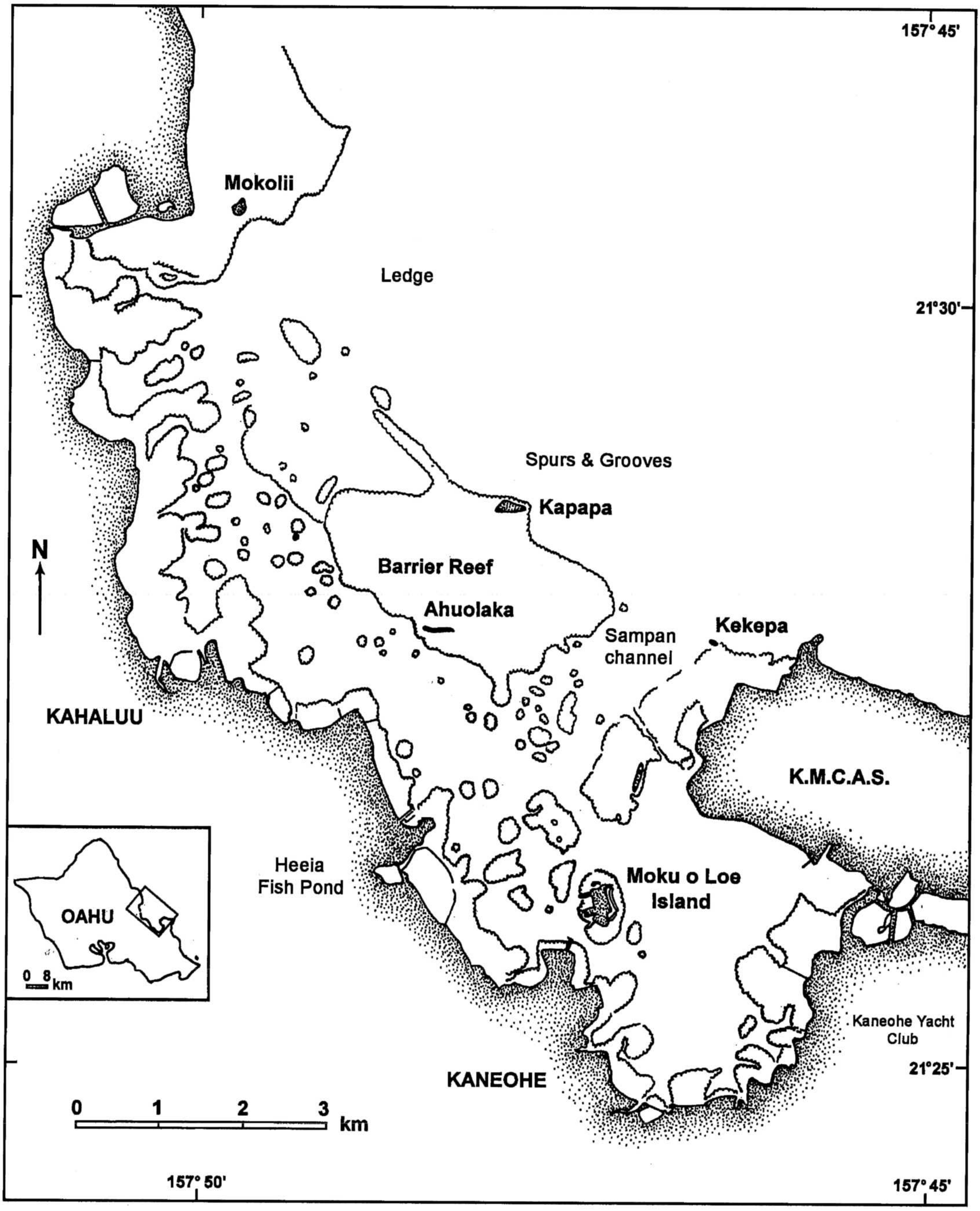

FIGURE 1. Map of Kāne'ohe Bay, O'ahu, Hawaiian Islands.

My move to the Hawaiian Islands, after nearly 20 yr of working in the Atlantic Ocean studying small, cryptic species, provided an excellent opportunity to extend these studies to the Pacific Ocean. From 1990 to 1995 a total of 75 small rotenone stations was made both within Kāne'ohe Bay and also outside the barrier reef in the spur and groove system and ledge area. Results from these stations form the basis for this paper. The purpose of this paper is to provide baseline information on the small fishes present in Kāne'ohe Bay and their relative abundance in various habitats and to investigate if predictable assemblages occur in specific habitats. Although Wayne Baldwin (deceased) kept a list of Kāne'ohe Bay fishes, when he left Hawai'i he discarded the list and there are no copies. Thus, there is no information on the species known to occur in the bay.

MATERIALS AND METHODS

Collection Techniques

The only collecting method that can quantitatively sample assemblages of small, cryptic fishes is the use of ichthyocides such as rotenone. When small amounts of rotenone are applied to relatively small areas within a specific habitat, it is possible to obtain information concerning the fish assemblages (species and their relative abundances) living in that habitat. The collecting stations were made with1.75 liters of liquid rotenone mixed with 0.25 liter of liquid soap (Ivory) and 0.33 liter of 5% powdered rotenone. Divers spread this mixture underwater over approximately 90 m^2 of specific habitat at 75 different stations. Fishes affected by the rotenone then were picked up by divers and later preserved in a 10% formalin solution. This collecting technique favors smaller, sedentary, and often cryptic species and underestimates the larger, more mobile species that can avoid an ichthyocide cloud, and thus the species collected should not be considered representative of the total fish community present.

The number of stations (collections) made at each of 10 different habitats was distributed as follows: deep spur and groove, 13 m and greater (15); shallow spur and groove, 1.5–12.9 m (16); sheltered patch reefs inside the bay, 0–4.5 m (11); open patch reefs near channels such as the Sampan, 0–3.1 m (11); ledge drop-off, 19.8–28.6 m (8); shelf above ledge, 9.2–12 m (2); rocky shore, 0–1.2 m (8); mangrove, 0–0.31 m (1); tide pool, 0.31 m (1); algae/rubble, 0–1.2 m (2). Sampling of habitats was not in relation to the proportion of their relative abundance or area. In analyzing separate families, only stations where that family was taken were used, often resulting in fewer stations. Some habitats, such as heavy algal patches, docks at marinas, and mangroves at Coconut Island, were not sampled because they are near highly populated areas where ichthyocides should not be used.

Data Analysis

All stations (75) were used in compiling the list of species taken. Detrended correspondence analysis (DCA) was used to identify clusters of similar stations (based on numbers of individuals of each species present) in ordination space (Gauch 1982). Only those stations where conditions were judged to have been good for making broadcast stations were included in the detrended correspondence analysis of assemblage structure (70). Thus, stations where strong currents swept the ichthyocide away from the station or when it was judged that the ichthyocide was not working properly were not included. Only stations with two or more species of the family being analyzed were used for DCA. I used the Canoco 4 package (ter Braak and Smilauer 1998) with the rare species downweighting option for DCA. Habitats for each station were identified on the plots and clusters of stations from the same habitat encircled by a minimal polygon, relating similar collections to specific habitats. Drawing minimal polygons is subjective, but polygons were constructed in such a way as to include as few different habitats as possible, striving for exclusive polygons containing stations from only one habitat.

Data on percentage occurrence for each species by habitat were calculated by dividing the total number of stations where that species was captured by the total number of stations containing members of its family (or a larger group such as Anguilliformes) made at a particular habitat. This was done rather than using the total number of samples as the denominator because there are some habitats in which certain fish families may never occur. Percentage relative abundance at a specific habitat was calculated by dividing the number of individuals of a species taken at that habitat by the total number of that species taken. The same procedure was used for assemblages identified using DCA, but only included stations with two or more species. Thus, for families where habitat assemblages were identified using DCA, two tables are presented.

Fish assemblages identified by DCA were examined to determine which species were dominant members of that habitat assemblage. Only species that were present in 50% or more of the stations were considered as dominant species, with the remainder being associated species.

Subsequent to my rotenone stations Kenneth R. Longenecker and Ross C. Langston (University of Hawai'i) continued to study the biology of small fishes in Kāne'ohe Bay. They have kindly provided me with more specific habitat information and data on additional species occurring within the bay. Information provided by Longenecker and Langston is credited by the notation (L & L).

The number of species of each family known to occur in Hawaiian waters was obtained from a draft manuscript kindly provided by Bruce C. Mundy (National Marine Fisheries Service Honolulu Laboratory). Information on each cryptic family is presented in phylogenetic order; however, those noncryptic fishes that were taken incidentally, although listed in Table 1, are not treated further. The majority of the specimens collected during this study have been deposited at the California Academy of Sciences.

The genus for an undescribed goby is listed as *Coryphopterus* (*Fusigobius*) because of conflicting information in the literature. Randall (1995) placed *Fusigobius* in synonymy of *Coryphopterus*, but Thacker and Cole (in press) have argued that both genera are valid. Although Yoshino et al. (1999) placed *Limnichthys donaldsoni* in synonomy of *L. nitidus*, this action is questionable (R. Langston, pers. comm., March 2002) and thus I continue to use *L. donaldsoni* for the Hawaiian species.

RESULTS

The 75 rotenone stations resulted in a total of 192 species from 48 different families (Table 1). In addition 10 other small species (one blenny, four gobies, one frogfish, one scorpionfish, one angelfish, one sandperch, and one cardinalfish) are known to occur in the bay (specimens I have examined and identified for others) but were not taken in the rotenone stations, for a total of 202 species and 49 families. The family with the greatest number of species was the Gobiidae (22), followed by the Labridae (20), Scorpaenidae (14), Muraenidae (13), Pomacentridae (12), and Blennidae (12). The remaining families were represented by fewer than 10 species. The most abundant species were *Eviota epiphanes* at 42 stations with 2776 individuals, *Crystallodytes cookei* at 22 stations with 955 individuals, *Foa brachygramma* at 14 stations with 908 individuals, *Asterropteryx semipunctata* at 10 stations with 604 individuals, and *Cirripectes vanderbilti* at 27 stations with 353 individuals. Thirty-one species were represented by a single individual in the stations, and 46 species were taken at only one station.

Moringuidae (spaghetti eels)

Only a single species of this family, *Moringua ferruginea*, is known from the Hawaiian Islands. It was captured at four stations, two at the shallow spur and groove habitat (6.2–10.6 m) and two at the deep spur and groove habitat (13–14.5 m) (Table 2). Four individuals were taken at the deepest station and a single individual at each of the others. This is a burrowing species that is found in the sand accumulated in the groove.

Chlopsidae (false morays)

Kaupichthys hyoproroides is one of three false morays known from Hawaiian waters and was the only one captured in this study. Thirteen

TABLE 1

Fish Species Collected from Kāne'ohe Bay, O'ahu, Hawaiian Islands: Number of Stations Where Taken and Number of Individuals Collected

Taxa	No. Stations	No. Individuals
Moringuidae (spaghetti eels)		
Moringua ferruginea	4	7
Chlopsidae (false morays)		
Kaupichthys hyoproroides	4	13
Muraenidae (morays)		
Anarchias (2 or more species)	11	17
Gymnomuraena zebra	1	1
Gymnothorax eurostus	25	72
Gymnothorax flavimarginatus	3	6
Gymnothorax gracilicaudus	13	22
Gymnothorax melatremus	15	57
Gymnothorax meleagris	2	3
Gymnothorax rueppelliae	1	1
Gymnothorax undulatus	3	3
Uropterygius fuscoguttatus	2	2
Uropterygius inornatus	4	5
Uropterygius macrocephalus	4	26
Ophichthidae (snake eels)		
Ichthyapus vulturis	2	2
Leiuranus semicinctus	1	3
Congridae (conger eels)		
Conger cinereus marginatus	4	4
Conger oligoporus	2	3
Clupeidae (herrings)		
Herklotsichthys quadrimaculatus	3	16
Synodontidae (lizardfishes)		
Saurida flamma	5	7
Saurida gracilis	5	8
Synodus binotatus	6	10
Synodus dermatogenys	10	13
Synodus ulae	6	6
Carapidae (pearlfishes)		
cf. *Onuxodon fowleri*	1	1
Ophidiidae (cusk-eels)		
Brotula multibarbata	10	22
Bythitidae (viviparous brotulas)		
Grammonus waikiki	1	2
Antennariidae (frogfishes)		
Antennarius analis	1	1
Antennarius drombus	2	2
Antennarius commersoni	1	1
Antennarius nummifer	3	4
Belonidae (needlefishes)		
Platybelone argala platyura	1	1
Mugilidae (mullets)		
Neomyxys leuciscus	1	16
Atherinidae (silversides)		
Atherinomorus insularum	4	96
Holocentridae (squirrelfishes)		
Myripristis amaena	1	1
Myripristis berndti	2	2
Myripristis kuntee	4	19
Neoniphon sammara	1	8
Plectrypops lima	10	16
Sargocentron diadema	12	30

TABLE 1 (continued)

Taxa	No. Stations	No. Individuals
Sargocentron punctatissimum	19	71
Sargocentron xantherythrum	3	29
Aulostomidae (trumpetfishes)		
Aulostomus chinensis	3	3
Fistularidae (coronetfishes)		
Fistularia commersoni	1	1
Syngnathidae (pipefishes)		
Dunckerocampus baldwini	3	4
Doryrhamphus excisus excisus	15	33
Scorpaenidae (scorpionfishes)		
Dendrochirus barberi	5	7
Iracundus signifer	1	1
Scorpaenodes hirsutus	5	9
Scorpaenodes kelloggi	38	198
Scorpaenodes littoralis	2	3
Scorpaenodes parvipinnis	9	20
Scorpaenopsis brevifrons	6	7
Scorpaenopsis cacopsis	1	1
Scorpaenopsis diabolus	3	4
Sebastapistes ballieui	16	70
Sebastapistes coniorta	24	97
Sebastapistes fowleri	16	34
Sebastapistes galactacma	11	26
Taenianotus triacanthus	5	6
Caracanthidae (orbicular velvetfishes)		
Caracanthus typicus	5	7
Serranidae (sea basses)		
Cephalopholis argus	1	1
Liopropoma collettei	3	5
Plectranthias nanus	23	142
Plectranthias winniensis	1	1
Pseudogramma polyacanthum	22	178
Suttonia lineata	3	6
Priacanthidae (bigeyes)		
Heteropriacanthus cruentatus	4	8
Apogonidae (cardinalfishes)		
Apogon deetsie	1	3
Apogon erythrinus	37	377
Apogon kallopterus	35	205
Apogon maculiferus	2	3
Apogonichthys perdix	7	40
Foa brachygramma	13	912
Pseudamiops diaphanes	13	45
Lethrinidae (emperors)		
Monotaxis grandoculis	1	1
Mullidae (goatfishes)		
Parupeneus cyclostomus	1	1
Parupeneus multifasciatus	3	3
Chaetodontidae (butterflyfishes)		
Chaetodon auriga	1	2
Chaetodon fremblii	1	1
Chaetodon kleinii	1	1
Chaetodon lunula	2	5
Chaetodon miliaris	2	8
Chaetodon multicinctus	2	3
Chaetodon lunulataus	1	1
Chaetodon unimaculatus	2	2
Forcipiger flavissimus	2	2

TABLE 1 (continued)

Taxa	No. Stations	No. Individuals
Pomacanthidae (angelfishes)		
Centropyge potteri	16	48
Kuhliidae (flagtails)		
Kuhlia xenura	4	12
Pomacentridae (damselfishes)		
Abudefduf abdominalis	5	29
Abudefduf sordidus	3	6
Chromis agilis	1	1
Chromis hanui	20	139
Chromis ovalis	2	7
Chromis vanderbilti	23	187
Chromis verater	1	2
Dascyllus albisella	14	40
Plectroglyphidodon imparipennis	14	56
Plectroglyphidodon johnstonianus	15	31
Plectroglyphidodon sindonis	3	3
Stegastes fasciolatus	21	77
Scaridae (parrotfishes)		
Scarus sordidus	3	67
Labridae (wrasses)		
Anampses chrysocephalus	1	1
Anampses cuvier	1	1
Bodianus bilunulatus	1	1
Coris flavovittata	2	2
Coris gaimard	1	1
Coris venusta	9	94
Gomphosus varius	2	2
Halichoeres ornatissimus	12	21
Labroides phthirophagus	4	7
Macropharyngodon geoffroy	7	10
Novaculichthys taeniourus	1	1
Oxycheilinus bimaculatus	2	3
Pseudocheilinus evanidus	2	10
Pseudocheilinus octotaenia	10	17
Pseudocheilinus tetrataenia	19	46
Pseudojuloides cerasinus	2	3
Stethojulus balteata	17	77
Thalassoma ballieui	2	2
Thalassoma duperrey	29	142
Thalassoma trilobatum	5	39
Cirrhitidae (hawkfishes)		
Amblycirrhitus bimacula	32	269
Cirrhitops fasciatus	25	98
Cirrhitus pinnulatus	7	9
Paracirrhites arcatus	18	31
Paracirrhites forsteri	6	6
Creediidae (sandburrowers)		
Crystallodytes cookei	22	955
Limnichthys donaldsoni	24	239
Tripterygiidae (triplefins)		
Enneapterygius atriceps	24	309
Blenniidae (combtooth blennies)		
Blenniella gibbifrons gibbifrons	8	33
Cirripectes quagga	4	66
Cirripectes vanderbilti	26	349
Enchelyurus brunneolus	9	46
Entomacrodus marmoratus	6	88
Entomacrodus strasburgi	7	137

TABLE 1 (continued)

Taxa	No. Stations	No. Individuals
Exallias brevis	5	8
Istiblennius zebra	2	19
Omobranchus rotundiceps obliquus	5	82
Plagiotremus ewaensis	2	2
Plagiotremus goslinei	6	10
Callionymidae (dragonets)		
Callionymus decoratus	2	3
Draculo pogognathus	1	1
Synchiropus rosulentus	2	7
Gobiidae (gobies)		
Asterropteryx semipunctata	14	621
Bathygobius coalitus	3	32
Bathygobius cocosensis	7	83
Bathygobius cotticeps	1	2
Cabillus sp.	1	1
Eviota epiphanes	41	2,767
Eviota rubra	14	144
Eviota susanae	8	66
Coryphopterus sp. (*Fusigobius* sp.)	8	12
Gnatholepis anjerensis	10	225
Gnatholepis cauerensis	4	4
Hazeus nephodes	1	3
Pleurosicya sp.	4	11
Priolepis aureoviridis	11	24
Priolepis eugenius	21	168
Priolepis farcimen	8	12
Priolepis limbatosquamis	12	35
Psilogobius mainlandi	6	26
Trimma unisquamis	12	135
Kraemeridae (sandfishes)		
Kraemeria bryani	4	75
Acanthuridae (surgeonfishes)		
Acanthurus leucopareius	3	6
Acanthurus nigrofuscus	21	85
Acanthurus nigroris	3	16
Acanthurus triostegus	8	61
Ctenochaetus strigosus	13	43
Zebrasoma flavescens	3	5
Zanclidae (moorish idol)		
Zanclus cornutus	2	2
Sphyraenidae (barracudas)		
Sphyraena barracuda	1	1
Bothidae (lefteye flounders)		
Bothus mancus	1	1
Bothus pantherinus	3	3
Engyprosopon hawaiiensis	1	1
Samaridae (slender flounders)		
Samariscus triocellatus	18	39
Soleidae (soles)		
Aseraggodes borehami	1	1
Aseraggodes sp.	1	1
Aseraggodes therese	6	16
Balistidae (triggerfishes)		
Sufflamen bursa	1	2
Monocanthidae (filefishes)		
Cantherhines sandwichiensis	4	4
Cantherhines dumerilii	1	1

TABLE 1 (continued)

Taxa	No. Stations	No. Individuals
Pervagor aspricaudus	3	4
Pervagor spilosoma	15	21
Ostraciidae (boxfishes)		
Ostracion meleagris camurum	1	1
Tetraodontidae (puffers)		
Arothron hispidus	2	3
Canthigaster amboinensis	6	9
Canthigaster coronata	1	1
Canthigaster epilampra	1	1
Canthigaster jactator	30	112
Canthigaster rivulatus	1	1

individuals were captured from four deep spur and groove stations (13–15 m) (Table 2).

Muraenidae (moray eels)

The moray eels were the fourth most speciose family taken in this study; they were represented by 13 species, about a third of the total (42) species known from Hawaiian waters (Böhlke and Randall 2000). The most abundant species was *Gymnothorax eurostus* (Table 1), a species that was widely distributed across all habitats where eels were taken (Table 2). The next most abundant species was *Gymnothorax melatremus*, but this species was taken only outside the bay at the ledge and spur and groove habitats (5.8–28.5 m) (Tables 1 and 2). Eleven other species also have been taken only outside the bay, with only four species being taken only inside the bay (Table 2).

Most of the specimens of *Anarchias* taken in this study were lost while on loan for study. Böhlke and Randall (2000) demonstrated that there are four species in Hawaiian waters: *A. leucurus*, *A. seychellensis*, and two undescribed species. My specimens were identified before that publication and thus their identity is unknown. Böhlke (deceased) had identified some of the specimens as *A. seychellensis* and an undescribed species, but it is unknown if other species occur in the bay.

Ophichthidae (snake eels)

Only two of the 16 snake eels known from Hawaiian waters were taken in this study. Three individuals of *Leiuranus semicinctus* were taken at a single station at an open patch reef, whereas *Ichthyapus vulturis* was taken twice, once from a deep spur and groove and once at a shallow spur and groove station (6.4–15.2 m) (Tables 1 and 2). Snake eels burrow in the sand and thus are less likely to be collected than other eels and probably are more abundant than indicated by the data.

Congridae (conger eels)

At least 11 species of conger eels are known from Hawaiian waters, but most (7) are from deep water. Only two were taken in this study (Table 1). Four individuals of *Conger cinereus marginatus* were taken, one each from a shallow spur and groove station, a sheltered patch reef station, and two open patch reef stations, all shallower than 7.6 m. A total of three young individuals of *Conger oligoporus* was taken from two sheltered patch reef stations (Table 2).

Eel Assemblage Structure

All 19 eel species were analyzed together using detrended correspondence analysis (Figure 2). The two stations with eels from rock habitat were separate from all other eel stations but were not close together in ordination space. This is because both stations had eel species that did not occur at other stations. The three patch reef stations (two sheltered and one open) were separated from both the rock and all other stations and were

TABLE 2

Percentage Occurrence and Relative Abundance of Eel Species from Kāne'ohe Bay

Species	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Sheltered Patch Reef		Rock	
	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Muraenidae												
Anarchias sp.[a]	12.5	11.8	36.8	70.6	25	17.6						
Gymnomuraena zebra											20	100
Gymnothorax eurostus	33.3	6.9	90.9	50	88.9	23.6	100	9.7	50	1.4	20	8.3
Gymnothorax flavimarginatus					16.7	50	25	16.7			60	66.6
Gymnothorax gracilicaudus	66.7	9.1	45.4	40.9	55.5	45.4					20	4.5
Gymnothorax melatremus	33.3	12.3	81.8	36.8	55.5	50.9						
Gymnothorax meleagris	33.3	33.3	9.1	66.7								
Gymnothorax ruepelliae											20	100
Gymnothorax undulatus									50	33.3	40	66.7
Uropterygius fuscoguttatus			18.2	100								
Uropterygius inornatus			9.1	80	11.1	20						
Uropterygius macrocephalus											80	100
Moringuidae												
Moringua ferruginea			18.2	28.6	22.2	71.4						
Chlopsidae												
Kaupichthys hypoproroides			36.4	100								
Congridae												
Conger cinereus marginatus					11.1	25	50	50	50	25		
Conger oligoporus									100	100		
Ophichthidae												
Ichthyapus vulturis			9.1	50	11.1	50						
Leiuranus semicinctus							25	100				

Note: Number of stations with eels for each habitat as follows: ledge, 3; deep spur and groove, 11; shallow spur and groove, 9; open patch reef, 4; sheltered patch reef, 2; rock, 5.
[a] Contains two or more species.

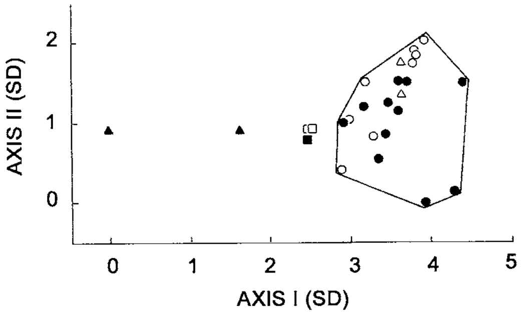

FIGURE 2. Detrended correspondence analysis of 24 stations containing eels from Kāne‘ohe Bay. Habitat classifications of stations indicated by the following symbols: ▲, rock; □, open patch reef; ■, sheltered patch reef; △, ledge; ○, shallow spur and groove; ●, deep spur and groove.

relatively close together, with only two species at each, all sharing *Gymnothorax eurostus*, and two sharing *Conger cinereus marginatus*. Stations from the remaining three eel habitats, shallow and deep spur and groove and ledge, all clustered together in ordination space. This analysis supported the pattern shown in Table 2.

Synodontidae (lizardfishes)

Of the 18 species of lizardfishes known from Hawaiian waters (some only from deep water), five species were collected from Kāne‘ohe Bay (Table 1). The most abundant species was *Synodus dermatogenys*, with 13 individuals being taken from 10 stations. This species was taken at all habitats where lizardfishes were collected except the ledge, with its greatest relative abundance at the deep spur and groove habitat (Table 3). The second most abundant species was *Synodus binotatus*, but it was taken only at the spur and groove habitats, especially the shallow spur and groove habitat. *Saurida flamma* appears to be a deeper-water species, having been taken at all ledge stations. It was taken at a single shallow spur and groove station, but this station was just slightly shallower than the cutoff for the deep spur and groove habitat (12.2 m). The other *Saurida* species taken, *S. gracilis*, is just the opposite, having been taken only at sheltered patch reef and rock habitats in shallower water. *Synodus ulae* was most abundant at the deep spur and groove habitat but also was collected at both patch reef habitats.

Assemblage structure was not analyzed for the lizardfishes because most stations only had one species. The greatest number of species taken together was two and this was only at five stations.

Carapidae (pearlfishes)

A single small pearlfish specimen was taken at the shallow spur and groove habitat. Because of its small size, identification is difficult, but it tentatively has been identified as *Onuxodon fowleri*.

TABLE 3

Percentage Occurrence and Relative Abundance of Lizardfish Species from Kāne‘ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Sheltered Patch Reef		Rock	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Saurida flamma	100	71.4	11.1	14.3	25	14.4						
Saurida gracilis									80	87.5	50	12.5
Synodus binotatus			33.3	60	75	40						
Synodus dermatogenys			44.4	38.5	25	15.4	50	30.8	20	7.7	50	7.7
Synodus ulae			44.4	66.7			25	16.7	20	16.7		

Note: Number of stations with lizardfishes for each habitat as follows: ledge, 3; deep spur and groove, 9; shallow spur and groove, 4; open patch reef, 4; sheltered patch reef, 5; rock, 2.

Ophidiidae (cusk-eels)

A total of 22 individuals of *Brotula multibarbata* was taken from 10 stations (Table 1). Five individuals were taken from two ledge stations, 15 from six deep spur and groove stations (>13 m), and two from two shallow spur and groove stations (9.2–12.9 m).

Bythitidae (viviparous brotulas)

Two individuals of *Grammonus waikiki* were taken at the ledge habitat at a depth of 24 to 26 m. These two specimens are the second and third known specimens of this species. The first specimen was taken off Waikīkī in 9.2 m.

Antennariidae (frogfishes)

Four of the 11 frogfish species known from Hawaiian waters were taken at Kāne'ohe Bay (Table 1). No more than one species was ever captured from the same station, and few individuals were collected. *Antennarius nummifer* was only collected from the ledge habitat (24.5–28.5 m), with a total of four individuals being taken from three stations. *Antennarius drombus* was taken twice from the shallow spur and groove habitat (4–12.8 m). A single individual of *Antennarius commersoni* was collected from the deep spur and groove habitat (13–13.9 m), and a single individual of *Antennarius analis* from the deep spur and groove habitat (13.9–14.6 m). *Histrio histrio* also has been recorded from the bay (L & L), rafting with *Sargassum.*

Holocentridae (squirrelfishes)

Although not small like most other fishes in this study, holocentrid species are nocturnal and hide in caves or holes and thus are susceptible to ichthyocides. Thus, unlike other larger species, the number of individuals collected probably is reflective of their relative abundances in Kāne'ohe Bay. Eight of the 17 species known from Hawaiian waters were taken in this study (Table 1). *Sargocentron punctatissimum* was the most abundant species and also occurred in a wide range of habitats, being absent only from the sheltered patch reef habitat (Table 4). It was most abundant at the spur and groove habitats. The second most abundant species, *Sargocentron diadema,* also occurred in a wide range of habitats, being absent only from the rock habitat. Its greatest relative abundance was in the deep spur and groove habitat. Although *Sargocentron xantherythrum* was the third most abundant species, it was taken only at the deep

TABLE 4

Percentage Occurrence and Relative Abundance of Squirrelfish Species from Kāne'ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Sheltered Patch Reef		Rock	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Myripristis amaena					14.3	100						
Myripristis berndti			10	50	14.3	50						
Myripristis kuntee			30	94.7					20	5.6		
Neoniphon sammara									20	100		
Plectrypops lima			80	81.2	42.9	18.7						
Sargocentron diadema	66.7	26.7	40	50	14.3	3.3	66.7	6.7	60	13.3		
Sargocentron punctatissimum	33.3	1.4	80	45.1	100	42.2	66.7	4.2			100	7
Sargocentron xantherythrum			30	100								

Note: Number of stations with squirrelfishes for each habitat as follows: ledge, 3; deep spur and groove, 10; shallow spur and groove, 7; open patch reef, 5; sheltered patch reef, 3; rock, 2.

spur and groove habitat (13–15.4 m). The other species also had limited distributions. *Neoniphon sammara* was taken only at the sheltered patch reef habitat and *Myripristis amaena* only at the shallow spur and groove habitat. *Myripristis berndti* was about equally abundant at the deep and shallow spur and groove habitats, whereas *Plectrypops lima* is a deeper-water species, being most abundant in the deep spur and groove habitat but also occurring in the shallow spur and groove habitat (11.6–12.9 m).

Only 13 of the 30 stations containing holocentrids had two or more species, nine from the deep spur and groove habitat, three from the shallow spur and groove, and one from the open patch reef. Detrended correspondence analysis of these few stations did not show any clustering of habitat-specific assemblages.

Syngnathidae (pipefishes)

Only two of the seven pipefish species known from Hawaiian waters were taken in this study, *Dunckerocampus baldwini* and *Doryrhamphus excisus excisus* (Table 1). *Dunckerocampus baldwini* is a deep-dwelling species, having only been taken at the ledge habitat where *D. excisus excisus* never was collected. Because percentage occurrence in a habitat is based only on stations where pipefishes were taken and only one species was taken at the remaining stations, the percentage occurrence was 100% for *D. excisus excisus* in the three habitats where it was collected. The relative abundance for this species was 3% in the sheltered patch reef habitat, 21.2% in the deep spur and groove, and 75.8% in the shallow spur and groove.

Scorpaenidae (scorpionfishes)

Fourteen of the 16 shallow-water scorpaenids known from Hawaiian waters were taken at Kāne'ohe Bay (Table 1). Scorpionfishes were taken at 54 different stations, with two or more species at 33. The greatest number of species taken at a single station was seven. The most abundant species taken was *Scorpaenodes kelloggi*, being taken at all habitats except sheltered patch reef and rock, but most often in the deep spur and groove (Table 5). It is commonly collected from the rubble in the spur and groove and from skeletal remains of *Pocillopora meandrina* in front of Turtle Rock (Kekepa) (L & L). The next most abundant species taken was *Sebastapistes coniorta*, which also occurred at all habitats except sheltered patch reef and rock and was taken most often in the deep spur and groove habitat, as were *Sebastapistes fowleri* and *Taenianotus triacanthus*. *Sebastapistes coniorta* usually is found in live colonies of *Pocillopora meandrina*. *Dendrochirus barberi* was taken only inside the bay at patch reef and rock habitats, most often at sheltered patch reefs, and is common in sheltered rubble and active at night (L & L). The only other species that was taken at the sheltered patch reef habitat was *Scorpaenodes parvipinnis*, which also occurred in the spur and groove habitats. *Scorpaenopsis brevifrons* occurred at the ledge and spur and groove habitats; *Sebastapistes galactacma* only at spur and groove habitats; and *Sebastapistes ballieui*, *Scorpaenodes littoralis*, and *Scorpaenodes hirsutus* only at spur and groove and open patch reef habitats. *Scorpaenopsis diabolus* was taken only at deep spur and groove, open patch reef, and rock habitats. Two species, *Iracundus signifer* and *Scorpaenopsis cacopsis*, each were represented by only one individual; however, L & L have collected *S. cacopsis* from the deep spur and groove and drop-off habitats. L & L also have taken *Pterois sphex* with spear from the ledge habitat.

Whereas individual species appeared to demonstrate habitat differences, analysis of the 33 stations where scorpionfish species cooccurred using DCA did not reveal any assemblages related to specific habitats. The stations from the open patch reef habitat fell outside a main cluster of stations from all other habitats, but they did not group together.

Caracanthidae (orbicular velvetfishes)

Only a single species of caracanthid is known from Hawaiian waters, the endemic *Caracanthus typicus*. Three individuals were taken from the shallow spur and groove habitat

TABLE 5

Percentage Occurrence and Relative Abundance of Scorpionfish Species from Kāne'ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Sheltered Patch Reef		Rock	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Dendrochirus barberi							25	28.6	66.7	57.1	50	14.3
Iracundus signifer	14.3	100										
Scorpaenodes hirsutus			20	77.8	5.9	11.1	12.5	11.1				
Scorpaenodes kelloggi	71.4	5	93.3	39.9	64.7	38.4	75	7.6				
Scorpaenodes littoralis			6.7	66.7			12.5	33.3				
Scorpaenodes parvipinnis			40	60	11.8	35			33.3	5		
Scorpaenopsis brevifrons	28.6	42.9	13.3	28.6	11.8	28.6						
Scorpaenopsis cacopsis					5.9	100						
Scorpaenopsis diabolus			6.7	25			12.5	25			50	50
Sebastapistes ballieui			33.3	15.7	47	58.6	37.5	25.7				
Sebastapistes coniorta	14.3	2.1	73.3	49.5	52.9	43.3	25	5.1				
Sebastapistes fowleri	14.3	8.8	60	61.8	23.5	23.5	25	5.9				
Sebastapistes galactacma			47.7	57.7	23.5	42.3						
Taenianotus triacanthus	14.3	16.7	66.7	16.7	11.8	50	12.5	16.7				

Note: Number of stations with scorpionfishes for each habitat as follows: ledge, 7; deep spur and groove, 15; shallow spur and groove, 17; open patch reef, 8; sheltered patch reef, 3; rock, 2.

(6.1–10.7 m) and three from the deep spur and groove habitat (13.8–14.8 m). Because this species lives among the branches of the coral *Pocillopora meandrina*, it will be taken only if a coral colony is at a particular station. The scorpionfishes *Sebastapistes coniorta* and *Sebastapistes ballieui* also live in the branches of this same coral species; however, *S. ballieui* also is found away from live coral. *Sebastapistes coniorta* was taken in each station where *C. typicus* was taken. The hawkfish *Paracirrhites arcatus* often perches on top of these same coral colonies.

Serranidae
(groupers and relatives [sea basses])

The six serranid species taken in this study are all small and cryptic except for a single individual of the introduced grouper *Cephalopholis argus* taken at the shallow spur and groove habitat. None of the serranids was taken inside the bay in sheltered habitat. The most abundant species, *Pseudogramma polyacanthum*, was taken at all habitats where serranids occurred, but was most abundant at the deep spur and groove habitat (Table 6). L & L have observed that *P. polyacanthum* appears to live deep in holes in the reef. The next most abundant species, *Plectranthias nanus*, was taken only at the ledge and spur and groove habitats, but was most abundant at the ledge habitat. Two species, *Suttonia lineata* and *Plectranthias winniensis*, were taken only at the ledge habitat and *Liopropoma collettei* only at the deep spur and groove habitat (13–14.7 m).

Detrended correspondence analysis demonstrated a clustering of ledge stations and a shelf station above the ledge that were well separated from all other stations, indicating a distinct assemblage of small, cryptic serranids at the ledge habitat (Figure 3). The ledge assemblage consisted of *Plectranthias nanus* at 100% of the stations, with a relative abundance of 85.7%. *Suttonia lineata* occurred at

TABLE 6

Percentage Occurrence and Relative Abundance of Serranid Species from Kāne'ohe Bay

Species	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Shelf above Ledge	
	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Cephalopholis argus					12.5	100				
Liopropoma collettei			30	100						
Plectranthias nanus	100	16.2	100	18.3	50	7				
Plectranthias winniensis	12.5	100								
Pseudogramma polyacanthum	12.5	1.1	100	78.1	100	18.5	100	1.7	50	0.6
Suttonia lineata	37.5	100								

Note: Number of stations with serranids for each habitat as follows: ledge, 8; deep spur and groove, 10; shallow spur and groove, 8; open patch reef, 2; bench above ledge, 2.

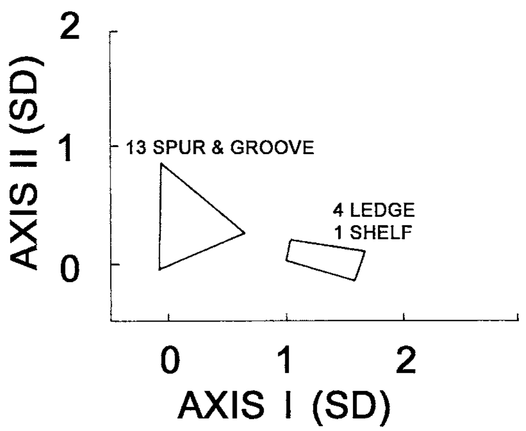

FIGURE 3. Detrended correspondence analysis of 18 stations containing serranids from Kāne'ohe Bay.

60% of the stations, with a relative abundance of 7.8%. The other two species present were *Pseudogramma polyacanthum* with values of 40% occurrence and 5.2% relative abundance and *Plectranthias winniensis* with values of 20% and 1.3%, respectively.

Priacanthidae (bigeyes)

Like the holocentrids, the bigeyes are not small, but are nocturnal and hide in caves or holes during the day, making them susceptible to ichthyocides. Only a single species, *Heteropriacanthus cruentatus*, was taken in this study and then only four times, all in spur and groove habitats ranging in depth from 3 to 14 m. L & L have observed large feeding aggregations in the grooves at night, and the species often shelters with the flagtail *Kuhlia xenura* in the day under reef overhangs.

Apogonidae (cardinalfishes)

Seven of the 10 shallow-water cardinalfish species known from Hawai'i were taken in this study (Table 1), and an eighth, *Apogon menesemus*, was taken by L & L at the deep spur and groove habitat. Cardinalfishes were taken at 53 stations, with two or more species at 34. Four species was the greatest number taken at any one station. The most abundant species was *Foa brachygramma*, but it only occurred inside the bay, being the most abundant at the sheltered patch reefs well inside the bay, with 100% occurrence and 99.3% relative abundance (Table 7). Other species, in order of decreasing abundance, were *Apogon erythrinus*, *A. kallopterus*, *Apogonichthys perdix*, and *Pseudamiops diaphanes*. *Apogon erythrinus*, a Hawaiian endemic (Greenfield 2001), was taken at all habitats but was most abundant in the spur and groove habitat and only rarely taken at sheltered locations inside the bay. It is a cryptic species that never is seen during the day (L & L). *Apogon kallopterus* occurred at all habitats, with its greatest relative abundance in the spur and groove habitat. L & L have noted that *A. kallopterus* forms visible shoals under overhangs and in

TABLE 7

Percentage Occurrence and Relative Abundance of Cardinalfish Species from Kāne'ohe Bay

Species	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Sheltered Patch Reef		Rock		Rubble/Algae	
	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Apogon deetsie	20	100												
Apogon erythrinus	20	0.8	86.7	53.8	93.3	33.9	100	10.9	9.1	0.3	100	0.3		
Apogon kallopterus	100	30.2	92.3	37.6	20	3.9	57.1	12.7	54.5	15.1			100	0.5
Apogon maculiferus	20	66.7	7.7	33.3										
Apogonichthys perdix							85.7	92.5					100	7.5
Foa brachygramma							14.3	0.1	100	99.3	100	0.6		
Pseudamiops diaphanes			61.5	66.7	26.7	31.1	14.3	2.2						

Note: Number of stations with cardinalfishes for each habitat as follows: ledge, 5; deep spur and groove, 13; shallow spur and groove, 15; open patch reef, 7; sheltered patch reef, 11; rock, 1; rubble and algae, 1.

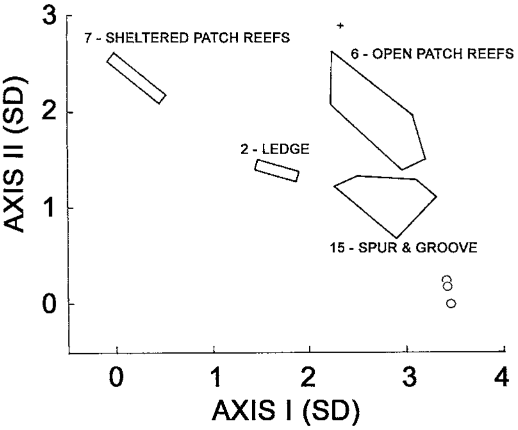

FIGURE 4. Detrended correspondence analysis of 34 stations containing apogonids from Kāne'ohe Bay. Habitat classifications of stations indicated by the following symbols: ○, shallow spur and groove; +, rubble/algae.

caves during the day. *Apogonichthys perdix* was taken only at the open patch reef habitat with 100% occurrence and at a single rubble/algae station in an open area. *Pseudamiops diaphanes* was taken only at open patch reef and spur and groove habitats, being most abundant in the latter. Two other species, *Apogon maculiferus* and *A. deetsie*, were only taken rarely, with *A. deetsie* once from the ledge habitat and *A. maculiferus* once from the ledge and once from the spur and groove habitat.

The habitat specificity demonstrated here for individual species is reflected in the detrended correspondence analysis. Cardinalfish assemblages formed four clusters related to specific habitats, with a fifth habitat represented by a single station (Figure 4). The habitat assemblages were spur and groove, ledge, open patch reefs, and sheltered patch reefs. The fifth habitat, represented by a single station, was rubble/algae. Stations made at sheltered patch reefs well inside Kāne'ohe Bay had an assemblage with *Foa brachygramma* as the most abundant species followed by *Apogon kallopterus*. Both species were present at all seven stations (Table 8). Patch reefs in more open areas near channels had *Apogonichthys perdix* and *A. erythrinus* at all six stations followed by *A. kallopterus*. *Apogon kallopterus* was the most abundant species at the three deep ledge stations along with *A. erythrinus*, *A. deetsie*, and *A. maculiferus*. *Apogon erythrinus* was the most abundant species in spur and groove habitat, being present at all 16 stations, followed by *A. kallopterus* and *Pseudamiops diaphanes*.

Pomacanthidae (angelfishes)

Only a single species of angelfish was taken in this study, *Centropyge potteri*. Forty-eight individuals were taken from 16 stations that were all either ledge or spur and groove hab-

TABLE 8

Percentage Occurrence and Relative Abundance of DCA Cardinalfish Habitat Assemblages from Kāne'ohe Bay

	Sheltered Patch Reef		Open Patch Reef		Ledge		Spur and Groove	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Foa brachygramma	100	94.4 (88)	16.7	1.0				
Apogon kallopterus	100	5.5 (11.6)	66.7	25.2	100	82.2	83.3	24.1
Apogon erythrinus	<1	0.1 (0.3)	100	36.9	33.3	6.7	100	64.9
Apogonichthys perdix			100	35.9				
Pseudamiops diaphanes			16.7	1.0			66.1	10.8
Apogon deetsie					33.3	6.7		
Apogon maculiferus					33.3	4.4	5.5	0.3

Note: Number of stations with two or more species and individuals for each habitat as follows: sheltered patch reefs, 7 stations, 621 individuals; open patch reefs, 6 and 103; ledge, 3 and 45; spur and groove, 18 and 353. Values in parentheses exclude one collection with 328 individuals of *Foa brachygramma*.

itats deeper than 8.7 m. L & L reported that *Desmoholacanthus arcuatus* is rarely seen in the deep spur and groove habitat.

Pomacentridae (damselfishes)

The damselfishes included semicryptic and noncryptic species. Although species such as *Abudefduf abdominalis* are large and swim high in the water column feeding on plankton, others such as *Stegastes fasciolatus* are found close to and shelter in the substrate. Still others, such as *Chromis vanderbilti*, although schooling above the coral while feeding on plankton, remain closer to the coral and dive into it when threatened. Even though not all damselfishes are small or cryptic and equally susceptible to ichthyocides, all species have been included in this analysis. Damselfishes were taken at 49 stations, 36 of which had two or more species. The greatest number of species taken at any one station was six. A total of 12 of the 17 damselfish species known from Hawaiian waters was taken in this study (Table 1). *Chromis vanderbilti* was the most abundant species, but only occurred outside the bay at the ledge, and deep and shallow spur and groove habitats, being most abundant at the deep spur and groove habitat (Table 9). *Chromis hanui* was the second most abundant species and had the same distribution as *C. vanderbilti*. *Chromis ovalis* was taken twice only in the deep spur and groove habitat (13–14.5 m). It is a larger, more mobile species and less likely to be collected than the other *Chromis* species. *Abudefduf abdominalis* also was less likely to be collected and was taken only in shallower areas. *Abudefduf sordidus* was taken only in the rock and tide pool habitats. *Dascyllus albisella* was taken at patch reef habitats in the bay as well as in the deep spur and groove habitat, apparently avoiding high-energy habitats. L & L have noted that it is very numerous in *Pocillipora endoux* heads along the ledge. *Stegastes fasciolatus* was the third most abundant species, with its greatest abundance in the shallow spur and groove habitat.

The species of *Plectroglyphidodon* show some habitat specificity. *Plectroglyphidodon sindonis* was taken only at the rock habitat, whereas *P. imparipennis* was taken only at the rock and shallow spur and groove habitats. *Plectroglyphidodon johnstonianus* was the most widespread species, being most abundant in the deep spur and groove habitat where it feeds on live coral, but never occurring with *P. sindonis*.

Although some damselfish species appear to exhibit a certain level of habitat specificity, detrended correspondance analysis did not reveal any species assemblages that were habitat specific.

Labridae (wrasses)

The wrasses also include cryptic and noncryptic species. Again, this habitat information is more reflective of the distribution in the bay of these small, cryptic species. A total of 20 of the 41 species known from the Hawaiian Islands was taken in this study. The most abundant species taken was *Thalassoma duperrey* followed by *Coris venusta* (Table 1). Five species were represented by only a single individual: *Anampses chrysocephalus*, *Anampses cuvier*, *Bodianus bilunulatus*, *Coris gaimard*, and *Novaculichthys taeniourus*. Three species, *Coris flavovittata*, *Gomphosus varius*, and *Thalassoma ballieui*, were represented by only two specimens each, and two species, *Oxycheilinus bimaculatus* and *Pseudojuloides cerasinus*, by three specimens each. Excluding these specimens where few individuals were taken, some of the other species appear to be habitat specialists, with *Pseudocheilinus evanidus* being taken only at the ledge habitat, and *Pseudocheilinus octotaenia* only at the ledge, the deep spur and groove, and the shelf above the ledge (Table 10). *Thalassoma trilobatum* was collected only at the shallow rock habitat, and *Halichoeres ornatissimus* and *Labroides phthirophagus* only at the spur and groove habitats. Other species such as *Thalassoma duperrey* are widepread in most habitats. Although no individuals were taken at sheltered patch reefs within the reef, it is doubtful that none occur there.

Detrended correspondence analysis resulted in the separation of stations into an exclusive minimal polygon containing 11 deep spur and groove stations and one shelf

TABLE 9

Percentage Occurrence and Relative Abundance of Damselfish Species from Kāne'ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Sheltered Patch Reef		Rock		Tidepool	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Abudefduf abdominalis					7.1	31			11.1	41.4	50	27.6		
Abudefduf sordidus											33.3	83.3	100	16.7
Chromis agilis	20[a]	100[a]												
Chromis hanui	100	20.9	100	66.2	28.6	12.9								
Chromis ovalis			18.2	100										
Chromis vanderbilti	80	12.8	90.9	47.1	64.3	40.1								
Chromis verater	20[a]	100[a]												
Dascyllus albisella			36.4	22.5			66.7	40	100	37.5				
Plectroglyphidodon imparipennis					78.6	64.3					66.7	35.7		
Plectroglyphidodon johnstonianus	20	3.2	72.7	54.8	21.4	25.8	50	16.1						
Plectroglyphidodon sindonis											50	100		
Stegastes fasciolatus			45.4	7.8	100	81.8	50	7.8			16.7	2.6		

Note: Number of stations with damselfishes for each habitat as follows: ledge, 5; deep spur and groove, 11; shallow spur and groove, 14; open patch reef, 6; sheltered patch reef, 6; rock, 6; tidepool, 1.

[a] Single individual.

TABLE 10

Percentage Occurrence and Relative Abundance of Wrasse Species from Kāne'ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Rock		Rubble/Algae		Shelf above Ledge	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Anampses chrysocephalus			10[a]	100[a]										
Anampses cuvier							25[a]	100[a]						
Bodianus bilunulatus	25	100												
Coris flavovittata			25[a]	100[a]										
Coris gaimard			10[a]	100[a]										
Coris venusta			10	2.1	50	96.8	25	1.1						
Gomphosus varius					14.3	100								
Halichoeres ornatissimus			50	33.3	50	66.7								
Labroides phthirophagus			30	85.7	7.1	14.3								
Macropharyngodon geoffroy			40	60	14.3	30							100	10
Novaculichthys taeniourus							25[a]	100[a]						
Oxycheilinus bimaculatus					7.1	33.3	25	66.7						
Pseudocheilinus evanidus	50	100												
Pseudocheilinus octotaenia	75	52.9	60	41.2									100	5.9
Pseudocheilinus tetrataenia	50	4.4	90	45.6	35.7	37	50	4.3					100	8.7
Pseudojuloides cerasinus	50	66.7	10	33.3										
Stethojulus balteata			10	2.6	71.4	48	75	10.4	40	33.8	100	5.2		
Thalassoma ballieui					7.1	50							100	50
Thalassoma duperrey	75	2.8	80	15.5	92.9	73.9	75	3.5	20	1.4			100	2.8
Thalassoma trilobatum									100	100				

Note: Number of stations with wrasses for each habitat as follows: ledge, 4; deep spur and groove, 10; shallow spur and groove, 14; open patch reef, 4; rock, 6; rubble/algae, 1; shelf, 1.
[a] Single individual.

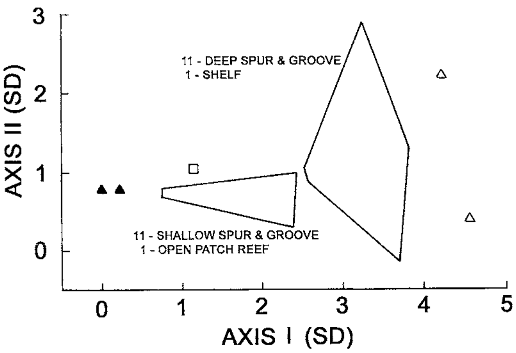

FIGURE 5. Detrended correspondence analysis of 29 stations containing labrids from Kāne'ohe Bay. Habitat classifications of stations indicated by the following symbols: ▲, rock; △, ledge; □, open patch reef.

station, and a smaller polygon made up of 11 shallow spur and groove stations and one open patch reef station. A second open patch reef station was close to the smaller polygon. Two ledge stations were well outside but close to the deep spur and groove polygon, and two rock stations were separate from other stations (Figure 5). Wrasses thus appear to exhibit a certain level of assemblage structure, with a depth gradient evident along the x axis of the plot with the shallow rock stations to the far left and the ledge stations to the far right. *Stethojulus balteata* and *Thalassoma trilobatum* occur together and are the dominant species at the rock stations (Table 11). The two deep stations differ from others because of the presence of *Pseudocheilinus octotaenia* at both and the presence of *Bodianus bilunulatus* and *Pseudocheilinus evanidus* at one, but they are not close together in ordination space (Table 11). The differences between the deep and shallow spur and groove assemblages is more subtle. All shallow spur and groove samples contain *Thalassoma duperrey*, whereas all deep samples do not.

TABLE 11

Percentage Occurrence and Relative Abundance of DCA Wrasse Habitat Assemblages from Kāne'ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Rock	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Anampses chrysocephalus			9.1[a]	9.5[a]						
Anampses cuvier							50	5.9		
Bodianus bilunulatus	50	10								
Coris flavovittata			9.1[a]	9.5[a]			50	5.9		
Coris gaimard			9.1[a]	9.5[a]						
Coris venusta			9.1	2.1	63.6	36.7	50	5.9		
Gomphosus varius					18.2	0.8				
Halichoeres ornatissimus			63.6	10.5	45.4	4.4				
Labroides phthirophagus			27.3	9.1	0.4	14.3				
Macropharyngodon geoffroy			45.4	18.2	1.2	30				
Novaculichthys taeniourus							50	5.9		
Oxycheilinus bimaculatus					9.1	0.4	50	11.8		
Pseudocheilinus evanidus	50	30								
Pseudocheilinus octotaenia	100	40	63.6	9.5						
Pseudocheilinus tetrataenia	50	5	90.9	29.5	18.2	2				
Pseudojuloides cerasinus	50	5	9.1	1						
Stethojulus balteata			18.2	3.2	81.8	14.5	100	41.2	100	51
Thalassoma ballieui					9.1	0.4				
Thalassoma duperrey	100	10	81.8	26.3	100	39.1	100	23.5	50	3.9
Thalassoma trilobatum									100	45.1

Note: Number of stations with two or more species and individuals for each habitat as follows: ledge, 2 stations, 20 individuals; deep spur and groove, 11 (includes 1 shelf station) and 95; shallow spur and groove, 11 and 248; open patch reef, 2 and 17; rock, 2 and 51.

[a] Single individual.

Pseudocheilinus octotaenia is absent from the shallow stations, but it is present at most of the deeper stations.

Cirrhitidae (hawkfishes)

Five of the six hawkfish species known from Hawaiian waters were taken in this study. The only species not taken was *Oxycirrhites typus*, a species that lives on gorgonians and black corals in deeper water, and the appropriate habitat was not present at the ledge habitat where we sampled; however, L & L have seen this species at Moku Manu at depths of 27 to 36 m. By far the most abundant hawkfish species taken was *Amblycirrhitus bimacula*, a small, very cryptic species that usually hides well into the coral or rock cover (Table 1). It was found most often and in the greatest abundance in the spur and groove habitats and also at the shelf and open patch reef habitats (Table 12). The next most abundant species was *Cirrhitops fasciatus*, with its greatest abundance in the deep spur and groove habitat. *Cirrhitops fasciatus* is often seen perching on branching corals (*Pocillopora meandrina* and *P. compresoa*) but used a wide range of subhabitats (e.g., algae-crusted rocks, overhangs, and holes in the reef) (L & L). *Paracirrhites arcatus*, the third most abundant species, also was most frequently taken in the deep spur and groove habitat and often was seen sitting on *Pocillopora meandrina* colonies. *Cirrhitus pinnulatus* and *Paracirrhites forsteri* were taken less frequently, with *P. forsteri* most abundant in the deep spur and groove habitat and *C. pinnulatus* at the spur and groove habitats and the rock habitat. *Cirrhitus pinnulatus* was the only hawkfish taken in the shallow rock habitat and is most often found under overhangs on the forereef and in front of Turtle Rock (Kekepa) (L & L). DCA did not reveal any assemblages related to specific habitats.

Pinguipedidae (sandperches)

Although no sandperches were taken in the rotenone stations, L & L have taken *Parapercis schauinslandi* from the sand area below the ledge.

Creediidae (sandburrowers)

Only two sandburrower species are known from Hawaiian waters and both were taken in this study. The most abundant species was *Crystallodytes cookei* followed by *Limnichthys donaldsoni* (Table 1). Both species occur where there is considerable water movement, and thus are absent from waters well inside the bay, and have been taken only at deep and shallow spur and groove habitats and at open patch reefs. *Crystallodytes cookei* was most abundant at the shallow spur and groove habitat, followed by the deep spur and groove habitat (Table 13). Outside the bay this spe-

TABLE 12

Percentage Occurrence and Relative Abundance of Hawkfish Species from Kāneʻohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef		Rock		Shelf above Ledge	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Amblycirrhitus bimacula			92.3	41.6	100	44.2	100	7.5			100	6.7
Cirrhitops fasciatus	60	10.2	92.3	54.1	57.1	22.4					100	13.3
Cirrhitus pinnulatus			15.4	22.2	21.4	33.3			100	45.5		
Paracirrhites arcatus	40	6.5	76.9	51.6	28.6	16.1					100	25.8
Paracirrhites forsteri			30.8	66.6	7.1[a]	16.7[a]					50[a]	16.7[a]

Note: Number of stations with hawkfishes for each habitat as follows: ledge, 5; deep spur and groove, 13; shallow spur and groove, 14; open patch reef, 4; rock, 2; shelf, 2.

[a] Single individual.

TABLE 13

Percentage Occurrence and Relative Abundance of Sandburrower Species from Kāne'ohe Bay

	Deep Spur and Groove		Shallow Spur and Groove		Open Patch Reef	
Species	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.	% Occ.	% Rel. Abun.
Crystallodytes cookei	60	21.7	92.9	74.1	75	4.2
Limnichthys donaldsoni	100	37.2	64.3	48.9	100	13.8

Note: Number of stations with sandburrowers for each habitat as follows: deep spur and groove, 10; shallow spur and groove, 14; open patch reef, 4.

cies can be found in tide pool/strand habitats (L & L). *Limnichthys donaldsoni* occurred at all the deep spur and groove and open patch reef stations where sandburrowers occurred, but had the greatest percentage occurrence at the deep spur and groove and greatest relative abundance at the shallow spur and groove habitat; however, L & L found it to be most abundant in the deep spur and groove habitat. L & L have noted that creedids were most abundant in sand next to algal turf–covered rock.

Tripterygiidae (triplefins)

Only a single species of triplefin, *Enneapterygius atriceps*, occurs in Hawaiian waters. This species is endemic to the Hawaiian Islands and Johnston Atoll. Because there is only one species in this family, percentage occurrence at habitats where the family occurred would be 100% for each habitat; however, it was taken at each habitat the following number of times followed by percentage relative abundance in parentheses: shelf, 1 (0.3%); rubble/algae, 2 (0.6%); rock, 3 (2.6%); open patch reefs, 4 (10%); deep spur and groove, 4 (10.4%); shallow spur and groove, 10 (76.1%). As is the case for most other blennioid fishes in Hawaiian waters, this species is most abundant in shallower water but is absent from protected areas with little water movement. The three stations at rock habitats were all in open areas. Near Turtle Rock (Kekepa) this species is most common in skeletal remains of the coral *Pocillopora meandrina* (L & L). The triplefin has been combined with the fishes in the family Blenniidae for analysis of assemblage structure.

Blenniidae (combtooth blennies)

Eleven of the 15 blenny species known from Hawaiian waters were taken in this study. A twelfth species, the introduced *Parablennius thysanius*, is found in the bay in fouling communities such as on dock floats, a habitat where stations using ichthyocides were not made. Although *Omobranchus rotundiceps obliquus*, probably another introduced species, was taken in our stations, it also is most abundant in fouling communities in sheltered areas of the bay. By far the most abundant species in our stations was *Cirripectes vanderbilti* (Table 1); this species was usually taken at three habitats, deep and shallow spur and grooves and the open patch reef, being most abundant in the shallow spur and groove (Table 14). *Entomacrodus strasburgi* was the second most abundant species but was taken at only two habitats, the shallow spur and groove, where it had the greatest percentage occurrence and relative abundance, and the rock habitat. Although all rock habitats have been grouped together, *E. strasburgi* was taken only in the very shallow water (0–0.9 m) behind Turtle Rock (Kekepa), a very high-energy area. In the shallow spur and groove habitat the greatest depth at which this species was captured was 4.6 m, also a high-energy area. *Cirripectes quagga* had the same distribution as *E. strasburgi*, but was more abundant behind Turtle Rock than in the shallow spur and groove. Both species appear to be habitat specialists occurring

TABLE 14

Percentage Occurrence and Relative Abundance of Blenny Species from Kāne‘ohe Bay

Species	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Shelf above Ledge		Open Patch Reef		Sheltered Patch Reef		Rock		Tidepool		Mangrove		Rubble/ Algae	
	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.
Blenniella gibbifrons gibbifrons					35.7	33.3							42.9	66.7						
Cirripectes quagga					14.3	7.6							28.6	92.4						
Cirripectes vanderbilti			62.5	21.5	85.7	72.8	50	0.6	85.7	4.6			14.3[a]	0.3[a]					100[a]	0.3[a]
Enchelyurus brunneolus									71.4	76.1	66.7	23.9								
Entomacrodus marmoratus													85.7	100						
Entomacrodus strasburgi					35.7	66.4							28.6	33.6						
Exallias brevis			12.5	25	14.3	50	50[a]	12.5[a]					14.3[a]	12.5[a]						
Istiblennius zebra													14.3[a]	5.3[a]	100	94.7				
Omobranchus rotundiceps obliquus											33.3	28	28.6	68.3			100	3.7		
Plagiotremus ewaensis	100[a]	50[a]			7.1[a]	50[a]														
Plagiotremus goslinei			25	30	28.6	70														

Note: Number of stations with blennies for each habitat as follows: ledge, 1; deep spur and groove, 8; shallow spur and groove, 14; shelf, 2; open patch reef, 7; sheltered patch reef, 6; rock, 7; tidepool, 1; rubble/algae, 1; mangrove, 1.

[a] Single individual.

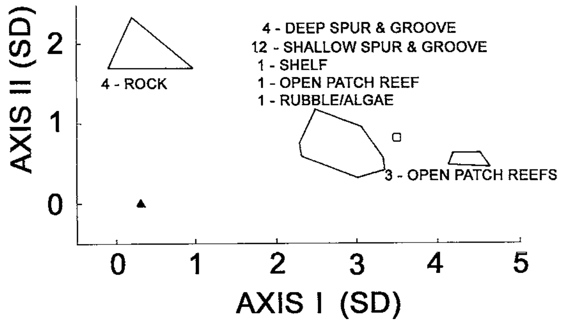

FIGURE 6. Detrended correspondence analysis of 28 stations containing blennioids from Kāne'ohe Bay. Habitat classifications of stations indicated by the following symbols: □, open patch reef; ▲, rock.

in shallow, high-energy areas. Although we were not able to sample at the crest of the barrier reef, it is reasonable to suspect that both species would be present in that habitat. *Blenniella gibbifrons gibbifrons* had a distribution similar to that of *E. strasburgi* and *C. quagga*, but was taken to a depth of 7.6 m in the shallow spur and groove, and only once at Turtle Rock, and twice on the windward shore of Kapapa Island where the other two species were not taken. *Entomacrodus marmoratus* also was taken only at shallow rock habitats, supporting the earlier findings of Strasburg (1953).

In contrast to the three species from high-energy habitats, *Enchelyurus brunneolus* occurred only in low-energy habitats. Along with *Omobranchus rotundiceps obliquus*, it was the only blenny (in addition to *P. thysannus*) found at sheltered patch reef habitats; however, it did not occur at reefs well inside the bay (i.e., near Kāne'ohe Yacht Club) where siltation was heavy and *O. rotundiceps obliquus* was common. *Omobranchus rotundiceps obliquus* was taken at these sheltered patch reefs, rock habitat well inside the bay near He'eia Fish Pond, and at mangrove habitat along the shore. As mentioned earlier it is most abundant in fouling communities, a habitat not sampled in this study.

Istiblennius zebra also is a habitat specialist that most commonly is found in tide pools. This species is known for its ability to leap from one pool to another (Strasburg 1953).

Exallias brevis, *Plagiotremus ewaensis*, and *Plagiotremus goslinei* were taken in low numbers in this study and thus less can be said about their habitat use, although *E. brevis* and *P. goslinei* were most abundant in the spur and groove habitats.

Assemblage structure was investigated for the blennioid fishes, combining the species from the Blenniidae and Tripterygiidae. DCA resulted in the recognition of three minimal polygons defining blennioid assemblages related to specific habitats (Figure 6). The analysis included nine blenny species and one triplefin from 28 stations where two or more species were present. Neither *Omobranchus rotundiceps obliquus* nor *Plagiotremus ewaensis* occurred with another blennioid. The greatest number of species taken together was six (five blennies and a triplefin) in 0–0.9 m behind Turtle Rock (Kekepa). Four of the rock stations clustered together in ordination space, with the fifth from Kapapa Island being well separated from all other stations because of the large number of *Blenniella gibbifrons gibbifrons* taken there. Three of the open patch reefs clustered together away from all other stations; however, one was associated with spur and groove stations and another near them. The third polygon included 12 stations from the shallow spur and groove habitat, four from the deep spur and groove habitat, as well as one open patch reef and one rubble/algae station. It appears that the habitat specificity of individual species is greater than that of blennioid assemblages, but some structure is present.

Callionymidae (dragonets)

Three of the eight dragonet species known from Hawaiian waters were collected from Kāne'ohe Bay, *Callionymus decoratus*, *Draculo pogognathus*, and *Synchiropus rosulentus* (Table 1). Although these fishes can be considered cryptic, they occur over sand, a habitat that we did not sample directly. Inhabitants of the sand habitat were taken in areas adjacent to patch reefs that were sampled or from the accumulated sand in the grooves of the spur and groove habitat. Thus, it is most likely that more callionymid species are present in Kāne'ohe Bay. The two stations with *C. decoratus* came from a sheltered patch reef well inside the bay, and the one with *D. pogognathus* from an open patch reef, whereas the two stations with *S. rosulentus* both were from the deep spur and groove habitat (13.5–15.3 m).

Gobiidae (gobies)

Nineteen of the 31 marine goby species known from Hawaiian waters were taken in this study (Table 1). A twentieth species, *Oxyurichthys lonchotus*, is common in Kāne'ohe Bay, but occurs on mud bottoms in the bay, a habitat we did not sample, in association with an alpheid shrimp, *Alpheus malabaracus*. A twenty-first species, *Mugilogobius cavifrons*, is introduced and occurs at mangrove habitats. It was taken around mangrove shores at the Hawai'i Institute of Marine Biology and in brackish pools at the north end of the bay. *Trimma taylori*, the twenty-second species, is very small, occurring in schools at the mouths of caves in deep areas such as the ledge habitat, and was taken by hand net, but not in our ichthyocide stations. *Bryaninops yongei*, the twenty-third species, lives on "sea whips" and none happened to be within our ichthyocide stations; however, this species has been collected separately from the ledge habitat (L & L).

The most abundant species in our stations was *Eviota epiphanes*, a species that was taken at all habitats except the ledge, tide pool, and mangrove habitats, but was most abundant in the shallow spur and groove habitat (Table 15). This species can be found on, in, or under any hard, nonliving substrate (reef rock, rubble, holes, overhangs) (L & L). The second most abundant species, *Asterropteryx semipunctata*, was taken only within the bay at patch reef and rock habitats, being most abundant in the sand adjacent to sheltered patch reefs. *Gnatholepis anjerensis*, the third most abundant species, also occurred most frequently in sand adjacent to sheltered patch reefs. The third species that also is usually present at these sheltered patch reefs is *Eviota susanae*, a specialist for this habitat. Although we did not collect from that habitat, *Eviota susanae* is also abundant in the fouling communities found on dock floats and pilings, the type locality of this species (Greenfield and Randall 1999). *Psilogobius mainlandi* is a "shrimp goby" that maintains a symbiotic relationship with *Alpheus rapax*. The shrimp burrows are built in the sand in protected areas and thus this species was taken at the sheltered patch reef stations. The fourth most abundant species, *Priolepis eugenius*, was most often found at open patch reef and shallow spur and groove habitats, both areas with considerable water movement.

The deeper habitats in this study (ledge, deep spur and groove, and shelf) also support goby species. *Eviota rubra* was taken exclusively from these habitats, occurring at all ledge stations and being most abundant there. Thus, *E. rubra* and *E. susanae* are two species that most likely would never encounter each other. *Gnatholepis cauerensis* was taken only at the ledge habitat, whereas *G. anjerensis* was most common around sheltered patch reefs (Randall and Greenfield 2001). *Trimma unisquamis* was most often found at the deep spur and groove habitat as was *Coryphopterus* sp. (*Fusigobius* sp.), which also occurred at the ledge as did *Priolepis aureoviridis* and *Priolepis limbatosquamis*.

The gobies in Kāne'ohe Bay exhibited considerable assemblage structure. DCA resulted in the recognition of several assemblages related to specific habitats. The analysis included 17 species from 51 stations with two or more goby species. The greatest number of species occurring together in a single station was seven from the deep spur and groove habitat. In a first analysis, because the fishes taken from the single tide pool station were

TABLE 15

Percentage Occurrence and Relative Abundance of Goby Species from Kāne'ohe Bay

	Ledge		Deep Spur and Groove		Shallow Spur and Groove		Shelf above Ledge		Open Patch Reef		Sheltered Patch Reef		Rock		Tidepool		Mangrove		Rubble/ Algae	
Species	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.	% Occ.	% Rel. Ab.
Asterropteryx semipunctata									28.6	3.1	100	92.1	12.5	4.8						
Bathygobius coalitus													25	12.5	100	87.5				
Bathygobius cocosensis											9.1	1.2[a]	50	90.4			100	7.2	50	1.2[a]
Bathygobius cotticeps													12.5	100						
Cabillus sp.			7.1	100[a]																
Coryphopterus sp.	12.5	8.3[a]	35.7	66.7	7.7	8.3[a]			14.3	16.7										
Eviota epiphanes			71.4	9.9	100	70.2	100	0.6	100	13.6	18.2	1.6	62.5	3.9					100	0.2
Eviota rubra	75	58.3	50	40.3			50	1.4												
Eviota susanae											72.3	100								
Gnatholepis anjerensis	12.5	0.9							14.3	0.4	72.3	98.7								
Gnatholepis cauerensis	25	50	14.3	50																
Hazeus nephodes											9.1	100								
Pleurosicya sp.	12.5	9.1[a]			7.7	18.2			14.3	63.6	9.1	9.1[a]								
Priolepis aureoviridis	50	50	28.6	25	15.4	8.3	50	16.7												
Priolepis eugenius			35.7	8.9	69.2	39.3			57.1	46.4			25	4.8	100	0.6[a]				
Priolepis farcimen																				
Priolepis limbatosquamis	25	34.3	57.1	57.1			100	8.6												
Psilogobius mainlandi											36.4	88.5	12.5	3.8[a]			100	7.7		
Trimma unisquamis			57.1	97	15.4	1.5	50	0.7	14.3	0.7[a]										

Note: Number of stations with gobies for each habitat as follows: ledge, 8; deep spur and groove, 14; shallow spur and groove, 13; shelf, 2; open patch reef, 7; sheltered patch reef, 11; rock, 8; tidepool, 1; rubble/algae, 2; mangrove, 1.

[a] Single individual.

so different from those of other stations (*Bathygobius coalitus* and *Priolepis eugenius*), the tide pool station plotted at one side of ordination space, forcing the other stations to cluster at the far side. When this single station was deleted and the data were analyzed again, greater separation was obtained. Four minimal polygons were recognized, a very tight cluster of all stations from sheltered patch reef habitats, a second with open patch reef and shallow spur and groove stations, a third with deep spur and groove and shelf stations, and a fourth with ledge stations (Figure 7). Three rock, one open patch reef, and one mangrove station were clustered together between the sheltered patch reef stations and all others.

The sheltered patch reef assemblage had three dominant species (present at more than 50% of the stations): *Asterropteryx semipunctata*, *Eviota susanae*, and *Gnatholepis anjerensis* (Table 16). Three additional associated

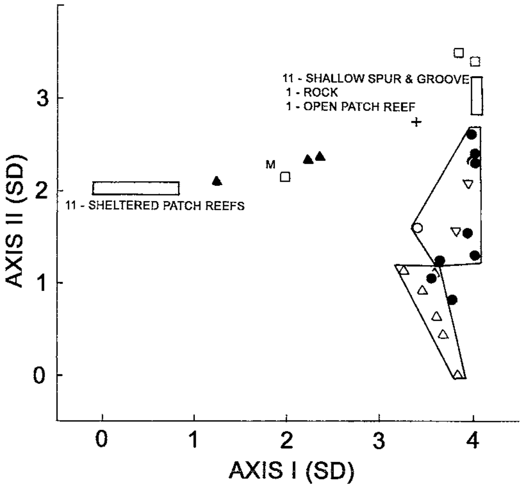

FIGURE 7. Detrended correspondence analysis of 50 stations containing gobiids from Kāne'ohe Bay. Habitat classifications of stations indicated by the following symbols: ▲, rock; △, ledge; □, open patch reef; ○, shallow spur and groove; ●, deep spur and groove; +, rubble/algae; ▽, shelf; M, mangrove.

TABLE 16

Percentage Occurrence and Relative Abundance of DCA Goby Habitat Assemblages from Kāne'ohe Bay

Species	Sheltered Patch Reef % Occ.	Sheltered Patch Reef % Rel. Ab.	Open Patch Reef and Shallow Spur and Groove % Occ.	Open Patch Reef and Shallow Spur and Groove % Rel. Ab.	Ledge % Occ.	Ledge % Rel. Ab.	Deep Spur and Groove and Shelf % Occ.	Deep Spur and Groove and Shelf % Rel. Ab.
Asterropteryx semiunctata	100	61.5						
Bathygobius coalitus	9.1	0.1						
Cabillus sp.							9.1	0.2
Coryphopterus sp.					16.7	0.9	45.4	1.5
Eviota epiphanes			100	91.8			90.0	53.7
Eviota rubra					100	72.2	81.8	11.4
Eviota susanae	90.1	11.8						
Gnatholepis anjerensis	72.2	23.9	6.7	0.05				
Gnatholepis cauerensis					16.7	0.9		
Pleurosicya sp.	9.1	0.1						
Priolepis aureoviridis			13.3	0.1	66.7	10.4	45.4	1.9
Priolepis eugenius			86.7	7.5			45.4	2.9
Priolepis farcimen			6.7	0.05	33.3	4.3	36.4	0.8
Priolepis limbatosquamis			33.3	0.3	33.3	10.4	90.9	2.5
Psilogobius mainlandi	36.4	2.6						
Trimma unisquamis			20	0.2			81.8	25.1

Note: Number of stations with two or more species and individuals for each habitat as follows: sheltered patch reefs, 11 stations, 930 individuals; open patch reefs and shallow spur and groove, 15 and 1907; ledge, 6 and 115; deep spur and groove and shelf, 11 and 525.

species were present. The open patch reef and shallow spur and groove assemblage had only two dominant species, *E. epiphanes* and *P. eugenius*, along with five associated species. The ledge assemblage also had only two dominant members, *E. rubra* and *Priolepis aureoviridis*, with four associated species. The deep spur and groove and shelf assemblage was repesented by four dominant species: *Priolepis limbatosquamis*, *Eviota epiphanes*, *Eviota rubra*, and *Trimma unisquamis*, and five associated species.

Kraemeridae (sandfishes)

The single species of kraemerid known from Hawaiian waters, *Kraemeria bryani*, was taken in this study. Similar to the sandburrowers in the family Creediidae, these tiny fishes live buried in the sand. This species was taken four times (total of 75 individuals), twice from shallow spur and groove and twice from deep spur and groove habitats. This species probably is much more abundant than our stations indicate because these small, nearly transparent fishes are easily missed when picking up fishes. Outside Kāne'ohe Bay it can be found in open tide pools and is usually most abundant near rocks (L & L).

Bothidae (lefteye flounders)

Although not particularly small, because of their ability to blend with the background and to cover themselves with sand, the bothids can be considered as cryptic fishes; however, because open sand areas were not specifically sampled, the few individuals taken were incidental and happened to be adjacent to reef or rocky shore areas being sampled. All stations were from shallow areas, 7.4 m or less, usually less than 3 m. Only three species were taken: *Bothus mancus*, *B. pantherinus*, and *Engyprosopon hawaiiensis* (Table 1).

Samaridae (slender flounders)

Samariscus triocellatus is one of two members of this family known from Hawaiian waters, and the only one from shallower waters. This species was captured 18 times with a total of 39 individuals (Table 1). This is a relatively small species that lives on the sand adjacent to reefs, especially in the sand grooves of the spur and groove system. It was taken four times at the ledge habitat, eight times at the deep spur and groove, five times at the shallow spur and groove, and once at the open patch reef habitat, but it also occurs on rubble (B. C. Mundy, pers. comm., January 2002). It usually was represented by only one or two individuals, with the greatest number being eight taken at a deep spur and groove station.

Soleidae (soles)

There are only three species of soles known from Hawaiian waters and all of these were taken in this study. A single individual of *Aseraggodes borehami* was taken adjacent to a patch reef in open water as was a single individual of *Aseraggodes* sp. (a species to be named by J. E. Randall in honor of R. Holcom). *Aseraggodes therese* was taken three times at the deep spur and groove habitat (10 individuals: 13.9–15.3 m), and three times at the shallow spur and groove habitat (6 individuals: 2.4–12.8 m).

Monacanthidae (filefishes)

Although filefishes are not considered to be cryptic, one species, *Pervagor spilosoma*, was taken often enough that it appears to be susceptible to rotenone stations and thus it is likely that our sampling may reflect its habitat use (Table 1). This species was taken six times at shallow spur and groove stations, six times at deep spur and groove stations, twice at open patch reef stations, and once at a shelf station. All of these habitats have considerable water movement; the species was not taken within the bay in more protected areas.

Tetraodontidae (puffers)

One species of puffer, *Canthigaster jactator*, was collected rather frequently, suggesting that our stations may reflect its habitat use even though it is not a cryptic species (Table 1). It was taken in each habitat the following number of times followed by percentage relative abundance in parentheses: deep spur and groove, 10 (60.7%); shallow spur and groove, 7 (15.2%); open patch reef, 5 (10.7%); sheltered patch reef, 3 (6.2%); ledge, 4 (6.2%); shelf, 1 (0.9%).

Combined Assemblage Structure

Data on assemblage structure for 10 taxa that were analyzed separately were combined to obtain information on potential larger assemblages related to specific habitats within Kāne'ohe Bay. The following 10 taxa with 123 species were included in this analysis: Apogonidae, Blennioidei, Cirrhitidae, Anguilliformes, Holocentridae, Labridae, Pomacentridae, Serranidae, and Scorpaenidae. Because only stations that contained two or more species were utilized for each taxon in earlier analyses, the total DCA did not include all stations or other families where earlier DCA was not performed. Four clusters of stations within ordination space were obtained (Figure 8). Eleven sheltered patch reef stations were clearly separated from all other stations. Eight ledge stations formed a distinct cluster, although one rubble station was included inside the minimal polygon and four open patch reef stations were close by. Fourteen shallow spur and groove, 14 deep spur and groove, seven open patch reef, and two shelf stations formed another relatively tight cluster. The fourth minimal polygon was large, containing nine rock and one mangrove station. The single tide pool station was separated from all other stations.

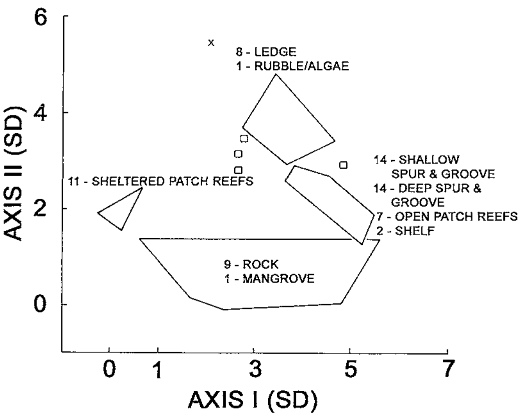

FIGURE 8. Detrended correspondence analysis of 72 stations combining data from Figures 2 through 7. Habitat classifications of stations indicated by the following symbols: □, open patch reef; X, tide pool.

DISCUSSION

A total of 202 species from 49 different families was recorded from Kāne'ohe Bay. Because only the smaller species and those susceptible to ichthyocide stations were taken, this only represents a portion of the total fish fauna present. Analysis of the distribution of these fishes in relation to specific habitats within the bay revealed that different families exhibited various levels of assemblage structure. The following families did not appear to exhibit any clustering of stations from specific habitats in ordination space: Cirrhitidae, Holocentridae, Pomacentridae, and Scorpaenidae. The eel families (Anguilliformes) only formed one minimal polygon containing spur and groove and ledge stations. The Serranidae and Labridae both formed two clusters. The Blennioidei formed three clusters. The Apogonidae and Gobiidae both formed four clusters. This conforms to findings from the Atlantic Ocean where different families exhibited different levels of assemblage structure (Greenfield and Johnson 1990*a,b*, 1999). These findings further support our earlier conclusion "... that the search for a single model to explain assemblage structure of coral-reef fishes is ill founded" (Greenfield and Johnson 1999). In addition, it appears that the same family may differ in its structure between the Atlantic and Pacific Oceans. Although the apogonids demonstrated strong structure in Kāne'ohe Bay, none was found in the Atlantic Ocean (Greenfield and Johnson 1990*b*), and the gobies also exhibited more structure in Kāne'ohe Bay (Greenfield and Johnson 1999).

When data from 10 families in Kāne'ohe Bay were combined, the distinctiveness of the patch reefs well inside the barrier reef (called sheltered patch reefs) from other habitats in the bay was reinforced. A number of different families have species that only occur in this habitat, resulting in an assemblage that is quite different from that found at other locations. This finding has broader significance because the sheltered patch reefs have been used extensively for studies in Kāne'ohe Bay, but clearly they are not representative of the fish fauna of the entire bay. Even studies of the larger, more conspicuous fish species in the bay may be impacted because the smaller fishes that may serve as food will be different. Friedlander and Parrish (1998) also found distinct assemblages in different habitats for larger fishes censused visually in Hawaiian waters.

The small fishes well within the bay and especially those at the open patch reef and spur and groove habitats have been little studied. The information in this paper can provide the basis for more detailed ecological studies of these fishes. Examination of the percentage occurrence and percentage relative abundance of each species in each habitat can reveal patterns deserving further investigation. For instance, the two blennies *Cirripectes quagga* and *C. vanderbilti* seldom occur together. The gobies and the cardinalfishes demonstrate a high level of habitat specificity, yet we know nothing about the factors contributing to these distributions. Do larvae of these species selectively settle into the adult habitat, do they settle randomly and then later move to specifiic habitats, or do they only survive in specific habitats? It is hoped that this research will lay the foundation for future studies of the small fishes of Kāne'ohe Bay.

ACKNOWLEDGMENTS

A project of this size could not have been accomplished without the help of my graduate students and others in the field. I specifically would like to thank Erin Baumgartner, Geoffrey Cockrel, Kassie Cole, Robert K. Johnson, Ross C. Langston, Kenneth R. Longenecker, Jeffrey Mahon, and John E. Randall for assisting in collections. Bruce C. Mundy allowed me to use a draft manuscript of a species checklist and I thank him for this. John E. Randall provided much assistance with species identifications and reviewed an early version of the manuscript. Ross C. Langston and Kenneth R. Longenecker reviewed the manuscript and provided valuable information. I thank Susan G. Mondon for preparing all figures. I thank the personnel of the Division of Aquatic Resources of the Hawai'i Department of Land and Natural Resources for granting permission to collect fishes using ichthyocides.

Literature Cited

Barlow, G. W. 1981. Patterns of parental investment, dispersal and size among coral-reef fishes. Environ. Biol. Fishes 6:65–85.

Boehlert, G. W., and B. C. Mundy. 1996. Ichthyoplankton vertical distributions near O'ahu, Hawai'i, 1985–1986: Data report. NOAA Tech. Mem. NMFS SWSC-235:1–148.

Böhlke, E. B., and J. E. Randall. 2000. A review of the moray eels (Anguilliformes: Muraenidae) of the Hawaiian Islands, with descriptions of two new species. Proc. Acad. Nat. Sci. Phila. 150:203–278.

Choat, J. H., and D. R. Bellwood. 1991. Reef fishes: Their history and evolution. Pages 39–66 *in* P. F. Sale, ed. The ecology of fishes on coral reefs. Academic Press, San Diego.

Fishelson, L. 1989. Bisexuality and pedogenesis in gobies (Gobiidae: Teleostei) and other fish, or, why so many little fish in tropical seas? Senckenb. Marit. 20:147–169.

Friedlander, A. M., and J. D. Parrish. 1998. Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. J. Exp. Mar. Biol. Ecol. 224:1–30.

Gauch, H. G. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge, Massachusetts.

Gosline, W. A. 1965. Vertical zonation of inshore fishes in the upper water layers of the Hawaiian Islands. Ecology 46:823–831.

Gosline, W. A., and V. E. Brock. 1960. Handbook of Hawaiian fishes. University Press of Hawai'i, Honolulu.

Greenfield, D. W. 2001. A revision of the

Apogon erythrinus complex (Teleostei: Apogonidae). Copeia 2001:459–471.

Greenfield, D. W., and R. K. Johnson. 1990*a*. Community structure of western Caribbean blennioid fishes. Copeia 1990:433–448.

———. 1990*b*. Heterogeneity in habitat choice in cardinalfish community structure. Copeia 1990:1107–1114.

———. 1999. Assemblage structure and habitat associations of western Caribbean gobies (Teleostei: Gobiidae). Copeia 1999:251–266.

Greenfield, D. W., and J. E. Randall. 1999. Two new *Eviota* species from the Hawaiian Islands (Teleostei: Gobiidae). Copeia 1999:439–446.

Hobson, E. S. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. 72:915–1031.

Miller, P. J. 1979. Adaptiveness and implications of small size in teleosts. Symp. Zool. Soc. Lond. 44:263–306.

Munday, P. L., and G. P. Jones. 1998. The ecological implications of small body size among coral-reef fishes. Oceanogr. Mar. Biol. Annu. Rev. 36:373–411.

Norris, J. E., and J. D. Parrish. 1988. Predator-prey relationships among fishes in pristine coral reef communities. Proc. 6th Int. Coral Reef Symp. 2:107–113.

Randall, J. E. 1995. *Fusigobius* Whitley, a junior synonym of the gobiid fish genus *Coryphopterus* Gill. Bull. Mar. Sci. 56:795–798.

Randall, J. E., and D. W. Greenfield. 2001. Preliminary review of the Indo-Pacific gobiid fishes of the genus *Gnatholepis*. Ichthyol. Bull. J. L. B. Smith Inst. Ichthyol. 69:1–17.

Strasburg, D. W. 1953. The comparative ecology of two salariin blennies. Ph.D. diss., University of Hawai'i, Honolulu.

ter Braak, C. J. F., and P. Smilauer. 1998. Canoco 4. Microcomputer Power, Ithaca, New York.

Thacker, C. E., and K. S. Cole. In press. Phylogeny and evolution of the gobiid genus *Coryphopterus*. Bull. Mar. Sci.

Yoshino, T., T. Kon, and S. Okabe. 1999. Review of the genus *Limnichthys* (Perciformes: Creediidae) from Japan, with description of a new species. Ichthyol. Res. 46:73–83.